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THE INTEGRATION OF THE PSU/NCAR MESOSCALE MODEL (MM5) WITH THE PHILLIPS LABORATORY CLOUD SCENE SIMULATION MODEL (CSSM)

A. A. Setayesh

Radex, Inc.
Three Preston Court
Bedford, MA 01730

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PHILLIPS LABORATORY
Directorate of Geophysics
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HANSCOM AIR FORCE BASE, MA 01731-3010

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A. A. Setayesh

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Three Preston Court
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An interface program has been developed to convert interpolated data from PSU/NCAR Mesoscale Model (MM5) to a set of appropriate input data in Navy Operational Regional Atmospheric Prediction System (NORAPS) format to be used in the Phillips Laboratory Cloud Scene Simulation Model (CSSM). The CSSM is an empirical model that produces high-resolution, multi-layer, four-dimensional cloud liquid water content fields. The MM5 with its utility programs such as TERRAIN, DATAGRID, RAWINS, and INTERP is a numerical model which is designed to predict mesoscale and regional-scale atmospheric flows. The MM5 terrain-following σ vertical coordinate output data has been interpolated with the INTERP program to pressure coordinate data. The interface program has used these pressure coordinate data and converted them to a set of binary data in NORAPS format, which the CSSM model uses for its meteorological input data. The converted MM5 data and a set of cloud data from CSSM are used to generate some sample cloud scene fields.

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1. INTRODUCTION

This paper describes a prototype integration of the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model Version (MM5) and the Phillips Laboratory Cloud Scene Simulation Model (CSSM). The MM5 is a numerical hydrodynamical model designed to predict mesoscale and regional-scale atmospheric circulation. The CSSM is an empirical model that produces high-resolution, multi-layer, four-dimensional cloud liquid water content fields. The CSSM uses two sets of data for its input, meteorological data and cloud data. CSSM currently uses meteorological input data fields from the Navy Operational Regional Atmospheric Prediction System (NORAPS). Therefore, in order to use the MM5 output data for CSSM, routines were needed to convert the MM5 data field to NORAPS data field format. This paper will describe the data conversion from MM5 to NORAPS formats.

The MM5 model consists of several components as shown in Figure 1. These components are auxiliary programs that are needed to generate and manipulate various data for MM5. These components are TERRAIN, DATAGRID, RAWINS, and INTERP. TERRAIN uses archived terrain data and interpolates these data to a mesoscale grid for a specified map projection [*Yong-Run and Chen*, 1994] . The output data from TERRAIN are used as input for DATAGRID, INTERP, and MM5. The DATAGRID module uses external coarse-scale meteorological data and horizontally interpolates the large-scale analyses to the finer mesoscale grid for use as initial and boundary conditions for the MM5. These data can be used by RAWINS and INTERP. RAWINS uses the DATAGRID data as a first guess, and introduces more detail into the mesoscale analyses by including additional point-source data and applying an iterative Cressman-type analysis [*Manning and Haagenson*, 1992]. INTERP uses data from analysis programs, such as DATAGRID and RAWINS, and transforms them to the mesoscale model grid. This includes vertical and horizontal interpolation, diagnostic computation, and simple data reformatting. INTERP specifically uses DATAGRID or RAWINS data as an input, and generates a model initial and boundary conditions file. INTERP has been used to produce data from MM5 for use by CSSM in the form of a NORAPS data set.

2. THE MM5-CSSM INTERFACE PROCEDURE

There are two ways to integrate MM5 and CSSM. One is to modify the MM5 and/or CSSM programs, and the second is to keep the MM5 and CSSM programs as is, and develop an interface program that converts the MM5 output to CSSM input. The second option, as represented in Figure 2, has been chosen because it will be independent from either the MM5 or the CSSM development. The MM5 and CSSM are both expected to be revised and enhanced in the future. The interface program however, need be modified only as changes occur in the MM5 output and/or the CSSM input data formats.

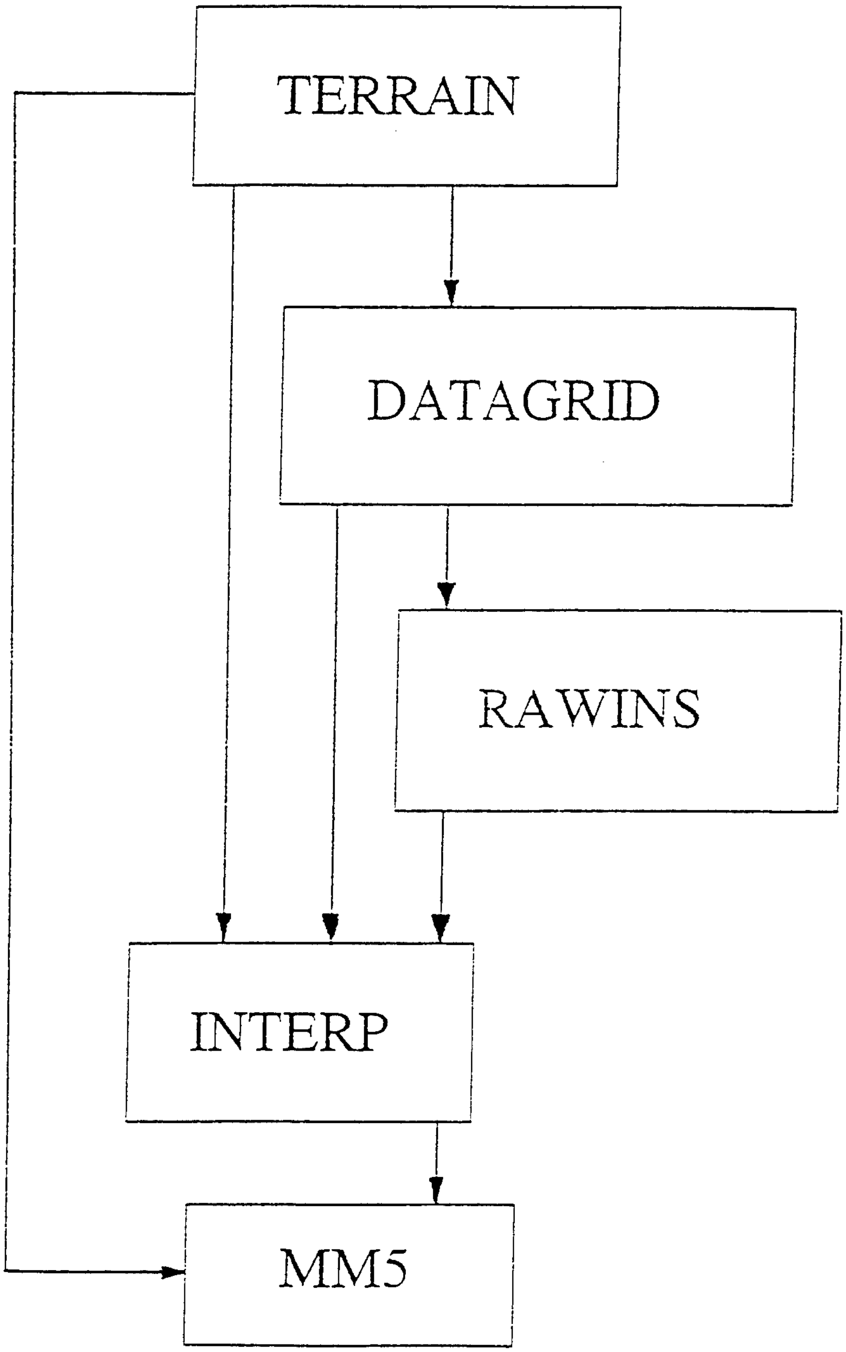

Figure 1. MM5 Modeling System flow chart.

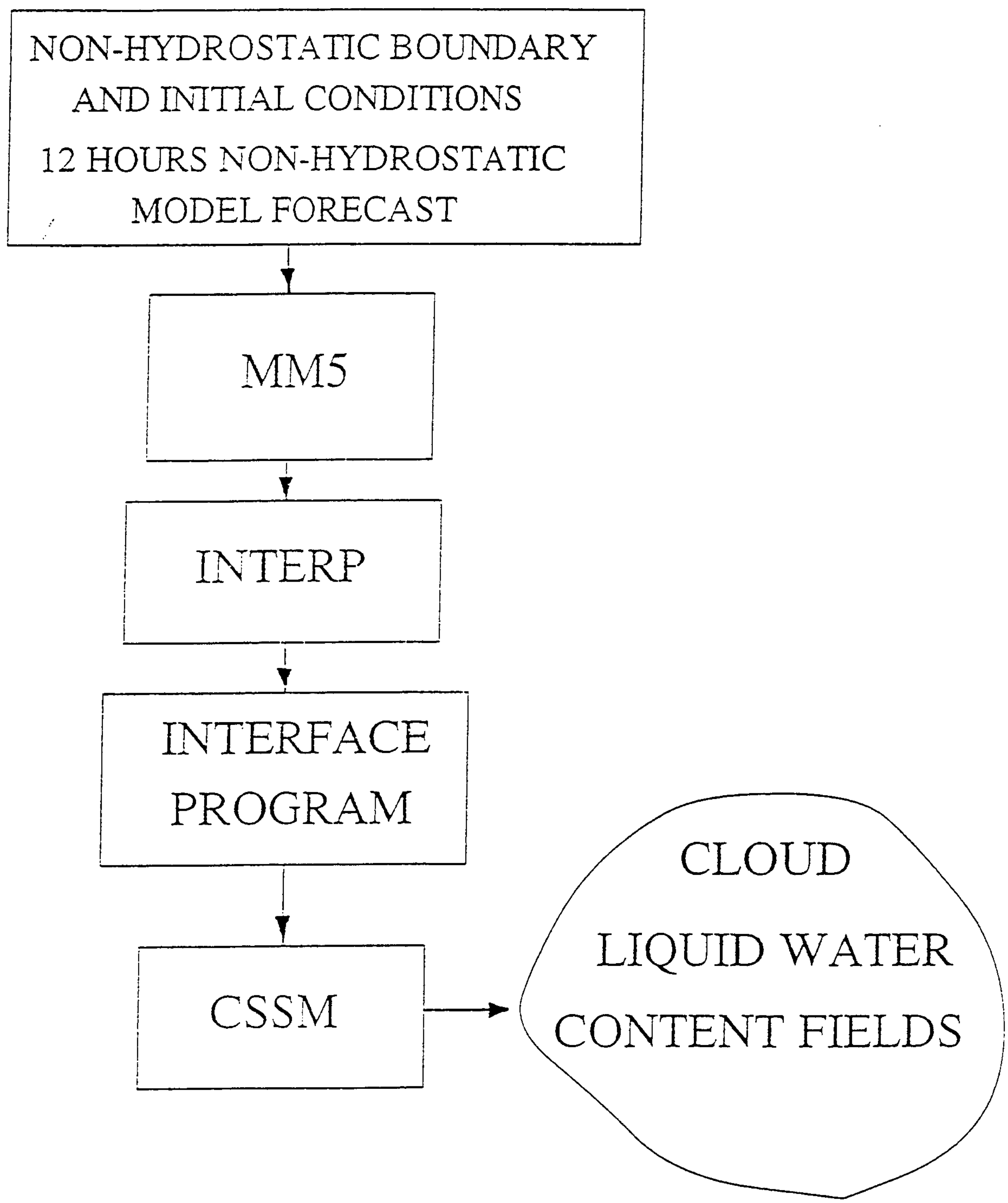

Figure 2. MM5-CSSM integration flow chart.

The MM5 output data are produced in terrain-following (σ) vertical coordinates, as shown in Figure 3, and NORAPS data are in pressure coordinates, as represented in Figure 4 [*Gill*, 1992]. To convert from σ to pressure coordinates, a C-Shell script was generated to be used as an input deck for the INTERP program. INTERP can convert the meteorological data from/to either of these types of coordinates. The interface program uses the output of INTERP to convert the necessary variables and parameters to NORAPS format to be used as input data fields for CSSM. This report is based on the only two sets of prototype data (at the time this report was written) available for the MM5 (workstation version) and the CSSM cloud data. The data for the MM5 is a 12-hour nonhydrostatic model forecast and nonhydrostatic boundary and initial conditions, and for the CSSM is the set of cloud layer data distributed with the model. The domain coverage for the MM5 data is 90 x 90 km, with 25 by 28 grid cells resolution. The data contained 12 levels of pressure, including mean surface pressure. The MM5 data has been generated for April 10, 1979, and started at 12 noon and continued to 12 midnight with a total of 720 minutes simulation time. The CSSM cloud data domain extends to 10 x 10 x 8 km with the 0.2 km grid resolution for all directions.

3. DESCRIPTION OF THE MM5/INTERP OUTPUT FORMAT

The MM5 input/output contains a record header and the data. The header consists of four two-dimensional arrays, which are called MIF, MIFC, MRF, and MRFC. The array MIF contains integer information, and array MIFC is the character array which describes the content of array MIF. The MRF contains floating point information, and MRFC is the character array for description of the MRF array.

The diagram of header arrays for the first dimension are as follows:

1-100	coarse domain information,
101-200	current domain information,
201-300	output fields information, and
301-1000	misc information.

The second array index of MIF, MIFC, MRF, and MRFC is reserved for the program number. These program numbers are as follows:

1	TERRAIN
2	DATAGRID
3	RAWINS
4	RAWINS surface FDDA
5	Model input
6	Model input on Sigma levels
7	Interpolated model output on Pressure levels.

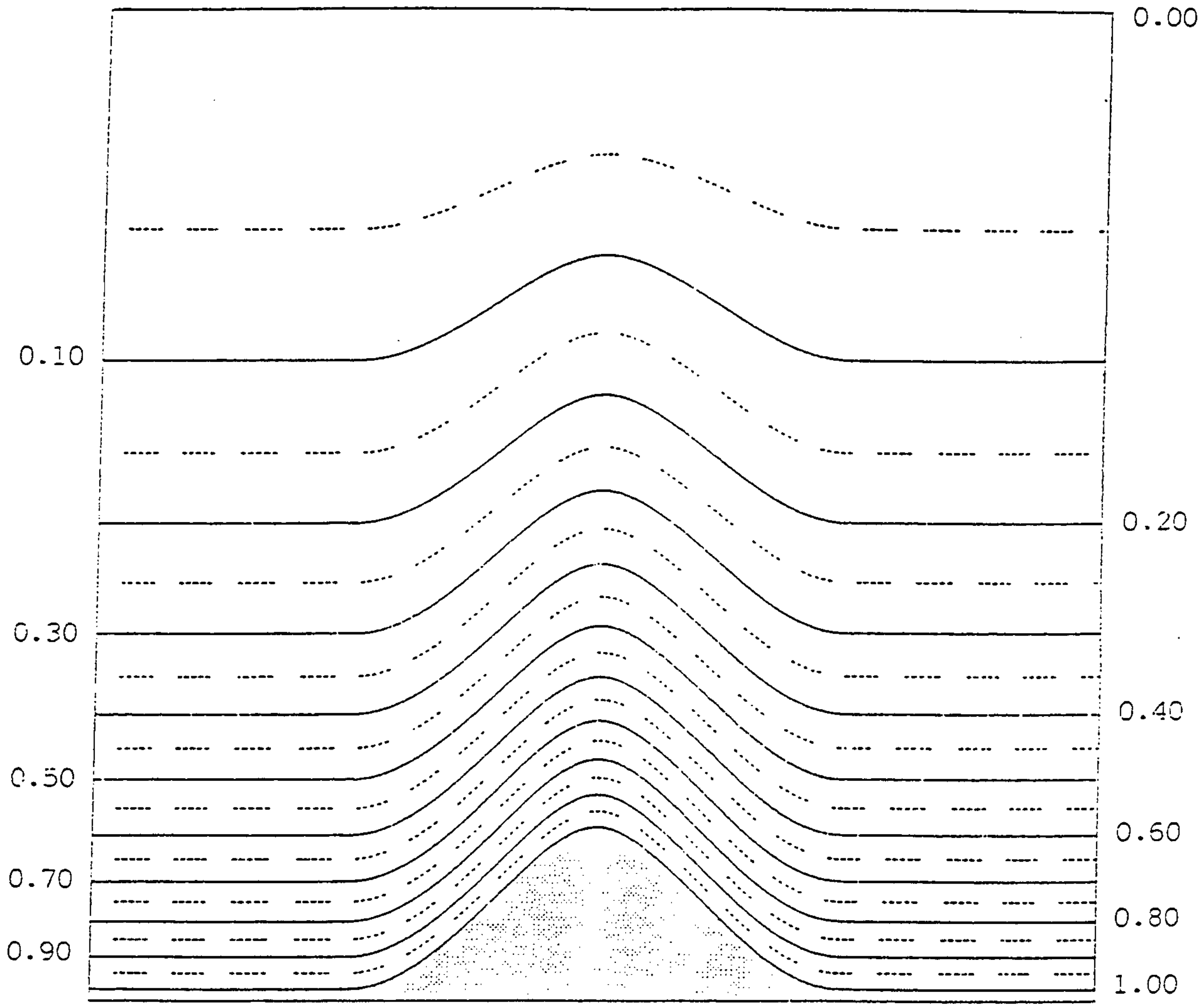

Figure 3. Vertical cross section detailing the structure of the sigma coordinate system of the mesoscale model MM5 with equi-spaced 11 full sigma levels (solid line) and the effective 10 half sigma layers (dashed line).

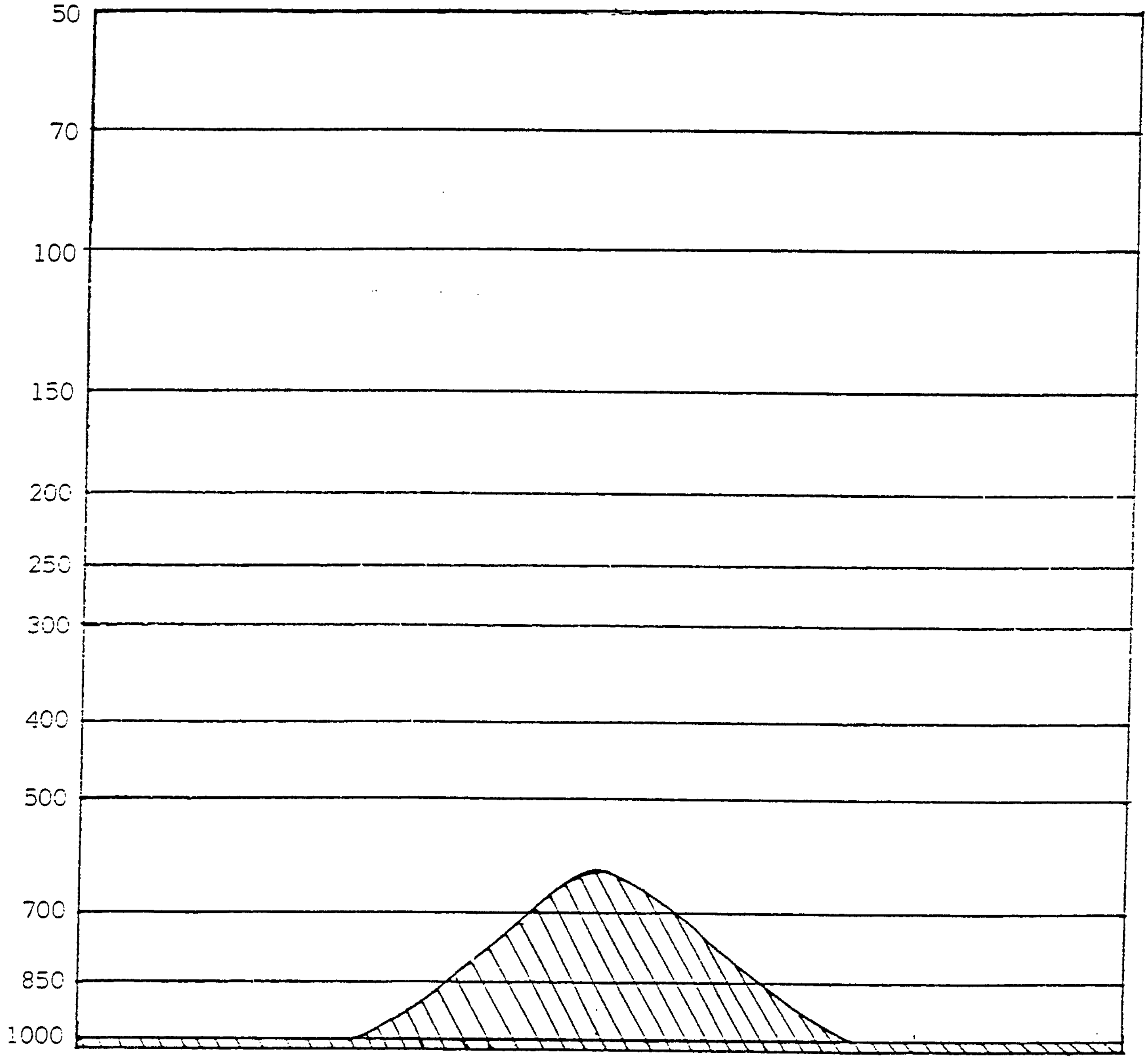

Figure 4. Vertical cross section detailing the structure of the pressure levels.

The program number 7 INTERP (Pressure level data) is the one used to generate data for the interface program. The field variables are given in 0-D, 1-D, 2-D, and 3-D formats. The MIF(1,7) contains the date for this particular MM5 output time period. The starting time for the MM5 output data is at 1979041012 (= MIF(2,7)). The other pertinent data are explained in junction with using NORAPS/CSSM ASCII data input in the next section. There are 17 (= MIF(202,7)) sets of 2-D fields, and 10 (= MIF(201,7)) sets of 3-D fields available from the output of MM5/INTERP. These 2-D and 3-D fields are stored as DUM2D(I,J,L) and DUM3D(I,J,K,L), where I,J are the dimensional indices, K represents vertical (pressure level) index, and L represents a field variable index (u wind, v wind, etc.).

4. DESCRIPTION OF THE NORAPS DATA FORMAT

The CSSM input consists of 14 data fields of NORAPS data, as follows [*Koenig, et al.*, 1994]:

data(1) = number of grid points along the x-direction of grid domain
data(2) = number of grid points along the y-direction of grid domain
data(3) = total number of analysis levels
data(4) = number of sigma levels in model, not used in the model
data(5) = type of projection:
- 1: Mercator
- 2: Lambert Conformal
- 3: Polar stereographic
- 4: Analytic
- 5: Spherical

data(6) = standard latitude #1 (not used)
data(7) = standard latitude #2 (used for Lambert Conformal)
data(8) = standard longitude of grid (not used)
data(9) = reference latitude (center point) of grid
data(10) = reference longitude (center point) of grid
data(11) = I-coordinate of reference latitude, longitude point
data(12) = j-coordinate of reference latitude, longitude point
data(13) = x-grid spacing in meters
data(14) = y-grid spacing in meters

Other related information is provided through the file names. Each file has a 36-character name in which each character, or group of characters, represent the velocity components, temperature components, height information, time initiation, time variations, fluid descriptions, mesh representation, pressure levels (both primary and secondary), level type of data, and field orientation. The file name has the following form:

nnnnfgddddddddddhhhmmsskkkkkllllttc

where

nnnn: 4-character representation for field type, where:
data - data header file (ASCII file)
topo - elevation (meters)
uuuu - u wind components (m/s)
vvvv - v wind components (m/s)
dptd - dewpoint depression (K)
tttt - upper air temperature (K)
temp - surface temperature (K)
dval - full geopotential height (m).

f: 1-character descriptor for fluid type, where
a: atmospheric
o: ocean.

g: 1-character representation for the grid, where,
1: NORAPS mesh.

dddddddddd: 10-character descriptor for forecast initialization date and time in yyyymmddhh format

hhhmmss: 7-character representation of the valid time of the field since forecast initialization, where,

hhh: hour(000-999)
mm: minute(00-59)
ss: second(00-59).

llll: 5-character descriptor for primary pressure level, the level for which the field is valid. For example, 850 mb would be given as 00850.

kkkk: 5-character representation of secondary pressure level. This is non-zero only to imply a thickness field with the thickness being the distance from the primary pressure level to secondary pressure level.

tt: 2-character descriptor for the pressure level type, where,
hs: height of a surface (primary and secondary levels in meters)
pr: pressure level(primary and secondary levels in millibar)
sf: surface (primary and secondary levels are zeros)
sl: mean sea level(primary and secondary levels are zero).

c: 1-character representation for field orientation, where
l: x-y field.

The following data and information are used from the MM5 output and the CSSM cloud data for CSSM ASCII data file "dataa11979041012000000000000000000sfl":

data (1) = MIF(104,1) : Domain grid dimension in I direction
data (2) = MIF(105,1) : Domain grid dimension in J direction
data (3) = MIF(101,7) : Number of pressure levels in the interpolated model output
data (4) = MRF(101,7) : Number of layers in MM5 output
data (5) = 2 (= Lambert Conformal) has been used
data (6) = MIF(221,7) : degrees latitude (south negative), 60 used
data (7) = MIF(221,7) : degrees latitude (south negative), 30 used
data (8) = MIF(223,7) : degrees longitude (west negative), 17.5 used
data (9) = MIF(221,7) : degrees latitude (south negative), 42.5 used
data (10) = MIF(223,7) : degrees longitude (west negative), 17.5 used
data (11) = 51 degrees used
data (12) = 51 degrees used
data (13) = MRF(101,1) : Domain grid distance given in km for MM5 used in meters for CSSM
data (14) = MRF(101,1) : Domain grid distance given in km for MM5 used in meters for CSSM

The other data in NORAPS format used in CSSM are binary files. From this particular MM5 data set, 287 binary files in NORAPS format have been generated using the following data from the MM5 output:

The u wind velocity (uuuu field), v wind velocity (vvvv field), upper air temperature (tttt field), and full geopotential height (dval field) are taken from DUM3D(I,J,K,1), DUM3D(I,J,K,2), DUM3D(I,J,K,9), and DUM3D(I,J,K,10), respectively.

The dewpoint depression (dptd field) has been calculated from upper air temperature DUM3D(I,J,K,9), relative humidity DUM3D(I,J,K,6), and a routine for calculating dewpoints [*Vietor*, 1993].

The I and J indices are from 2 to 24 and from 2 to 27 (avoiding the boundaries), respectively.

The vertical index is K = 1 to 12 (MIF(101,7)), where K = 1 for surface pressure, and 2 to 11 (MIF(101,7) which correspond to pressure levels of 1000 (MIF(103,7)), 925 (MIF(104,7)), 850 (MIF(105,7)), 700 (MIF(106,7)), 500 (MIF(107,7)), 400 (MIF(108,7)), 300 (MIF(109,7)), 250 (MIF(110,7)), 200 (MIF(111,7)), 150 (MIF(112,7)), and 100 (MIF(113,7)) millibars, respectively. These quantities are

generated for a 12 hour period at 3 hour intervals.

The above MM5 output and CSSM input conversion produces 275 binary files in NORAPS format, ready to be used in the CSSM program.

The surface temperature (temp field) is calculated from DUM3D(I,J,1,9), which represents temperature at the surface with the same time intervals described above. The elevation (topo field) and "elevation.dat" of the CSSM have been evaluated from the terrain data DUM2D(I,J,3). The last items in the NORAPS input were files named "slpra11979041012....sl". These were created from sea level pressure DUM2D(I,J,2) for a 12 hour time period at 3 hour intervals. The above MM5 quantities also produce an additional 12 binary files to be used in the CSSM program.

5. SAMPLE CLOUD SCENES

Figures 5 and 6 represent samples of cloud field simulations generated with the previously discussed cloud data from the CSSM and the meteorological data from the MM5. These figures are produced using the BOB rendering code [*Chin-Purcel*, 1992] in RGB image frame format, with relative cloud origin coordinates of (1000,1000,1000). Figures 5 and 6 use 50x50x40 cell resolutions for the cloud fields. The target coordinates for both figures are set to be at 1025,1025,1020. Figures 5 and 6 show the cloud scene at altitudes of 0.9 km and 1 km, respectively. The eye points are located at 21 and 24.5 km far from the center of cloud volume, respectively.

6. SUMMARY AND CONCLUSION

The MM5 output was converted from σ-coordinates to pressure coordinates using the INTERP program (one of the auxiliary programs in MM5 modeling system). The INTERP output was used to develop an interface program which converts INTERP output to NORAPS format data. The generated NORAPS format data was used as input for the CSSM, a cloud liquid water content field generator.

The interface program can be improved or upgraded when the CSSM has been completed and comprehensive documentation becomes available for MM5. The program can also be made more robust by testing other prototype data sets with each model.

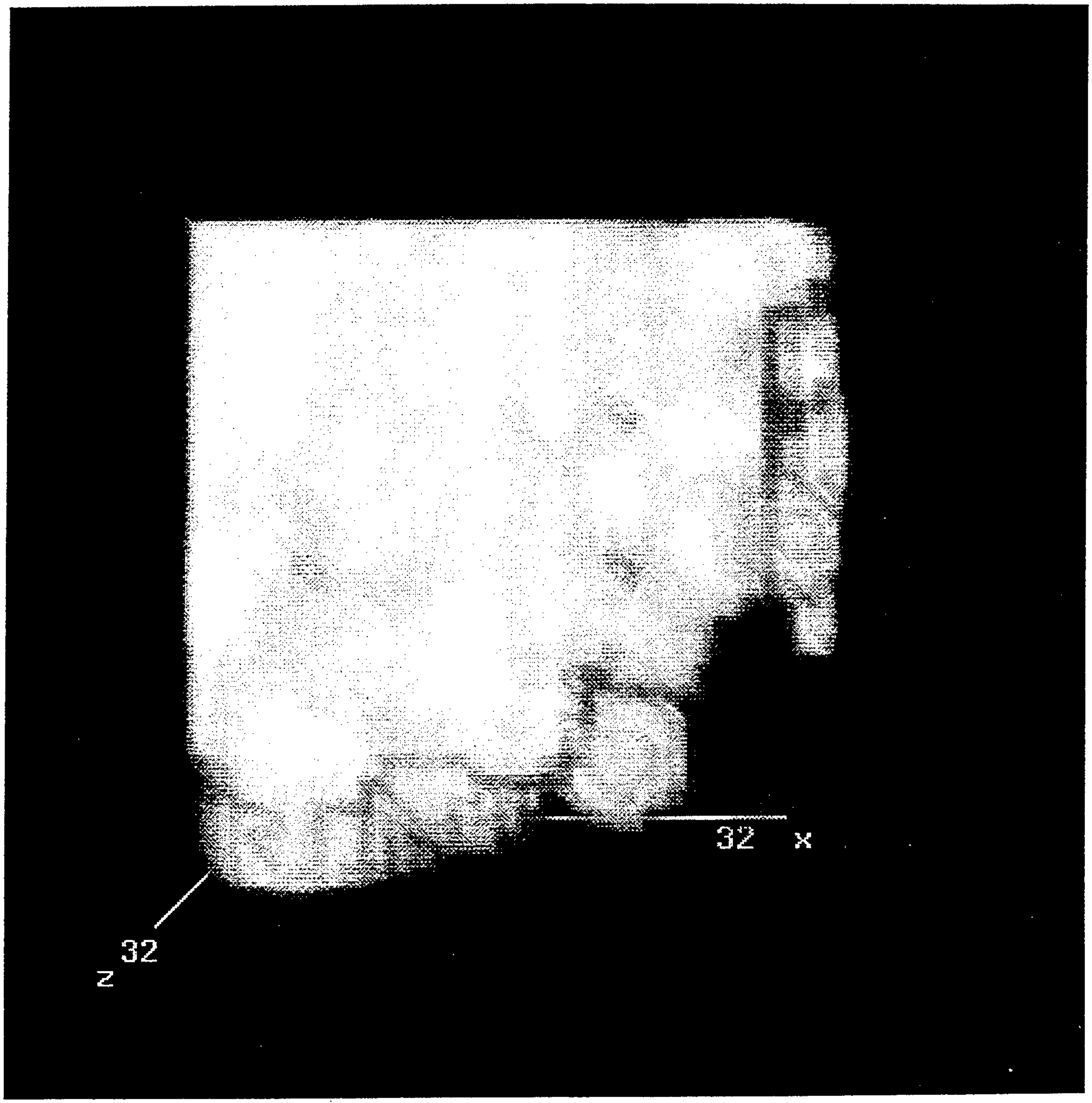

Figure 5. A sample cloud field using MM5 and CSSM data sets. At an altitude of .9km, the eye point is located 21km far from center of the cloud volume

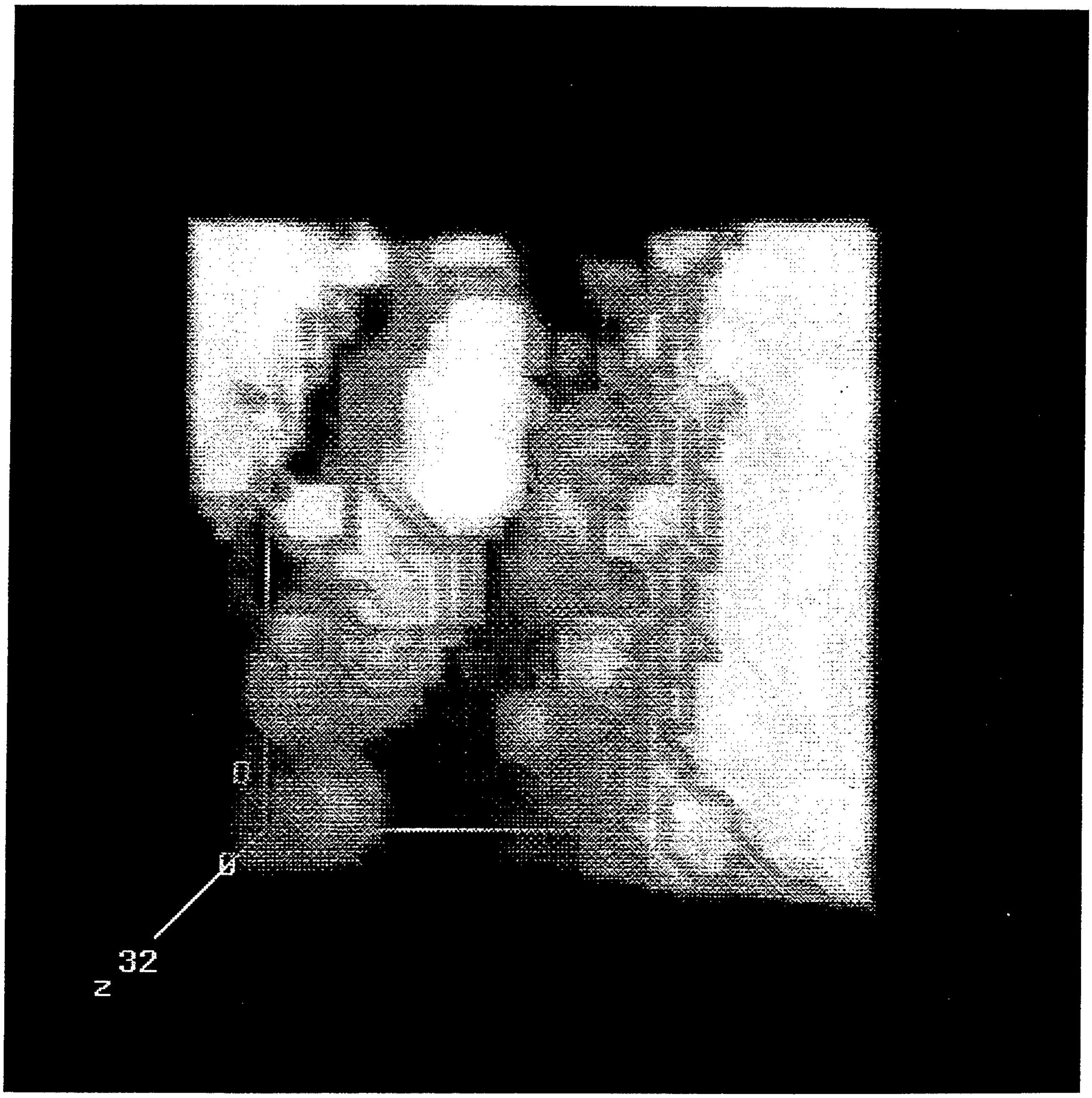

Figure 6. A sample cloud field using MM5 and CSSM data sets. At an altitude of 1km, the eye point is located 24.5km far from center of the cloud volume.

REFERENCES

Chin-Purcell, K., "Brick of Bytes", University of Minnesota Army High Performance Computing Research Center, DAAL03-89-C-0038, Army Research Office, 1992.

Gill, D. O., "A User's Guide to the Penn State/NCAR Mesoscale Modeling System", NCAR/TN-381+IA, NCAR, Boulder, Colorado, 1992.

Koeing, S. M., M. E. Lewis, and M. E. Cianciolo, "Atmospheric Scene Simulation Modeling and Visualization", TIM-7169-1, TASC, Reading, MA, 1994.

Manning, K. W. and P. L. Haagenson, "Data Ingest and Objective Analysis for the PSU/NCAR Modeling System: Programs DATAGRID and RAWINS", NCAR/TN-376+IA, NCAR, Boulder, Colorado, 1992.

NCAR, "A User's Guide to the Penn State/NCAR Mesoscale Modeling System (MM5)", to be published.

Vietor, D. "WXP4.8", Unidata Software, UCAR, Boulder, Colorado, 1993.

Yong-Run, G., S. Chen, "Terrain and Land Use for the Fifth-Generation Penn State/NCAR Mesoscale Modeling System (MM5)", NCAR/TN-397+IA, NCAR, Boulder, Colorado, 1994.

APPENDIX

The interface computer program is written in FORTRAN and C. The FORTRAN routine is designed to read INTERP interpolated data output. The C routines are designed to generate 36 character file names for each file which correspond to the NORAPS format. These file names contain information such as velocity components, temperature components, height information, initiation time, time variations, fluid descriptions, mesh representation, pressure levels, and field orientation. The FORTRAN routine then generates output files with 36 character file names with appropriate data contained in each file. The interface program can be obtained from Joel Mozer, PL/GPAA (e-mail: mozer@plh.af.mil).

The following steps have been taken in the process of developing an interface program and generating data from/for the MM5 and CSSM models:

1. Obtaining unpublished documents from NCAR for using the MM5 and INTERP programs.

2. Preparing prototype input data of 12-hour nonhydrostatic model forecast and nonhydrostatic boundary and initial conditions.

3. Running MM5 with the prototype data to produce meteorological data in σ coordinates.

4. Generating of a C-Shell script and running INTERP to interpolate MM5 output data from σ coordinate to pressure coordinate data. The generated data is stored in a file called "interp.out"

5. Using the interface program to read the header arrays of MIF, MRF, MIFC, MFRC and the data arrays of DUM2D and DUM3D from "interp.out".

6. Running the interface program to generate required data needed by the CSSM model. These data have been described earlier and are set of NORAPS formatted 36-character name data files.

7. Using the cloud data provided with the CSSM model and NORAPS formatted data to produce cloud scene data.

8. Rendered cloud scenes using the generated CSSM output data as an input into the ONYX cloud rendering code.